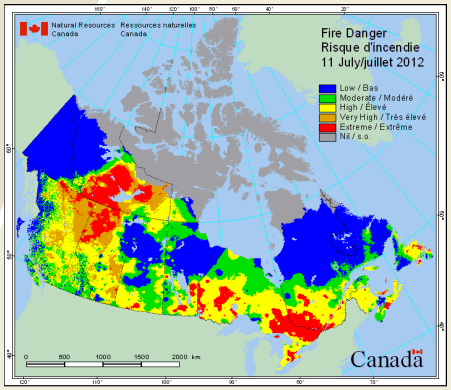
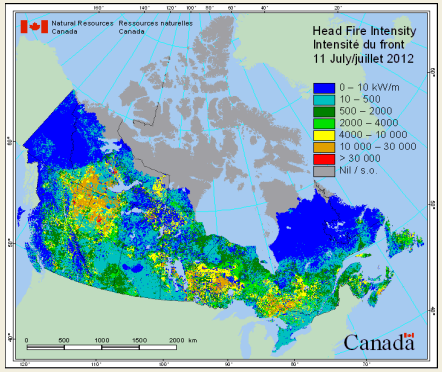
Ongoing activities in the development of a next generation of the Canadian Forest Fire Danger Rating System

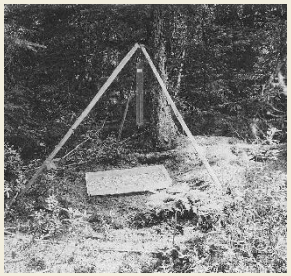




August 15, 2014

CFFDRS – Its History (20th century)



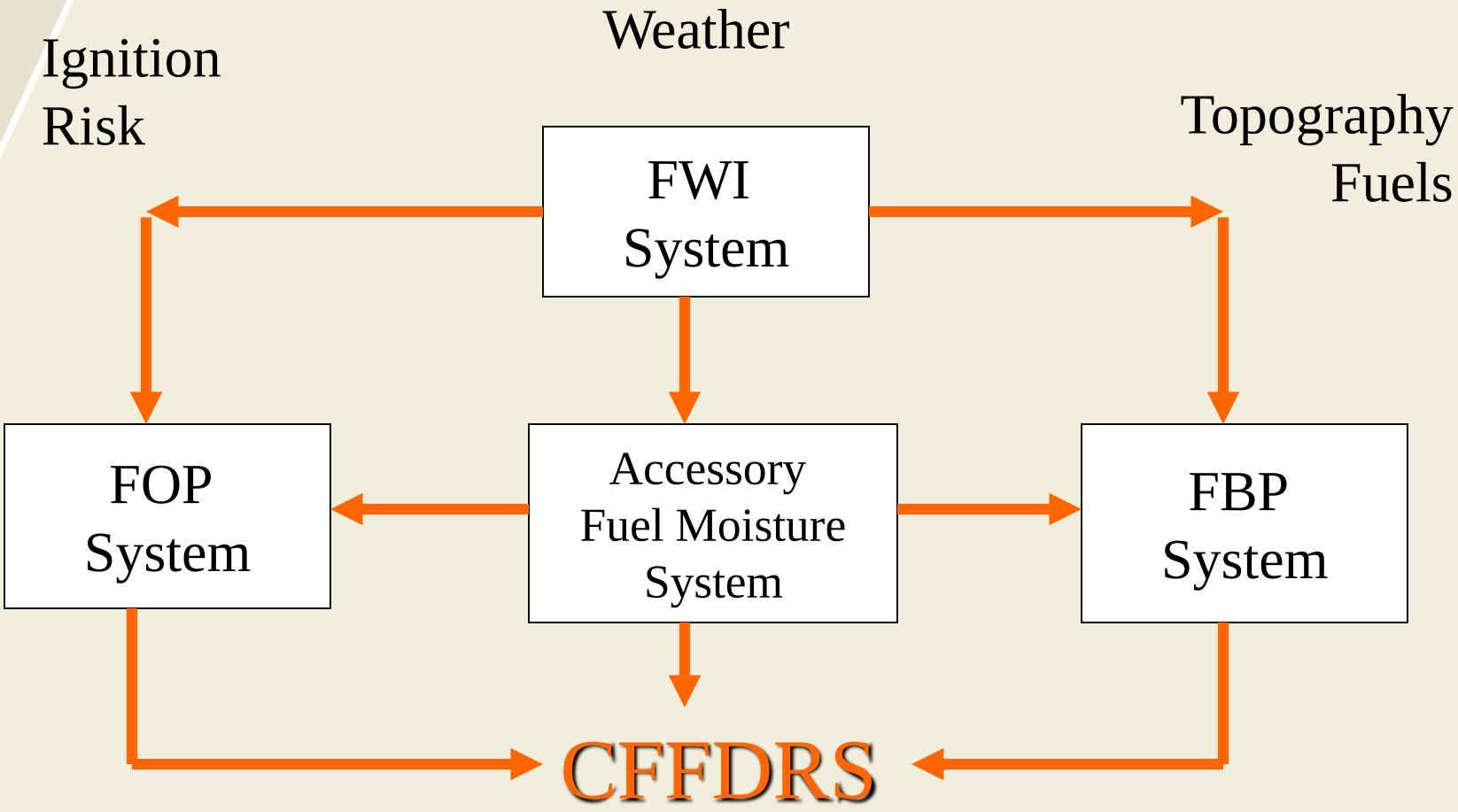



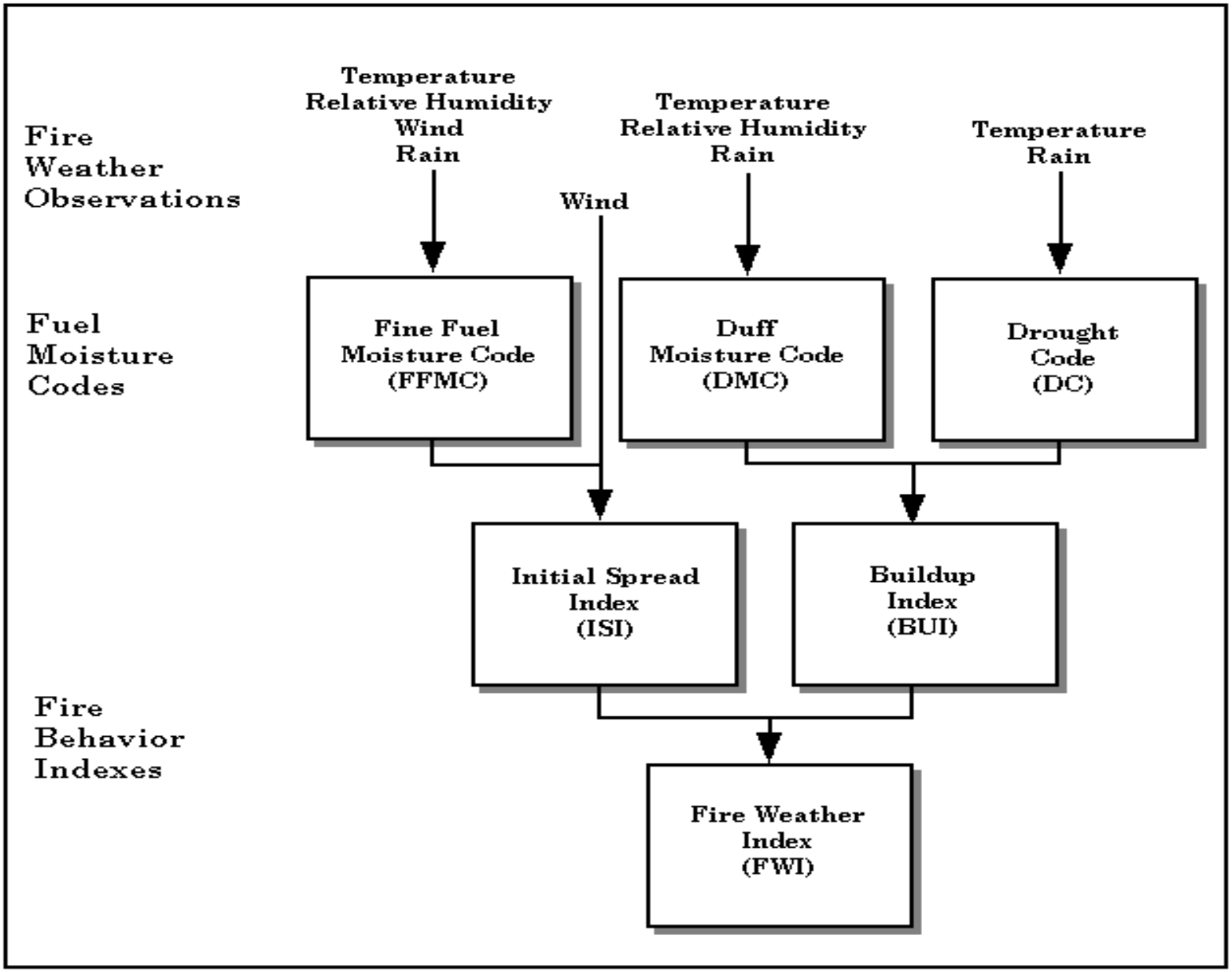


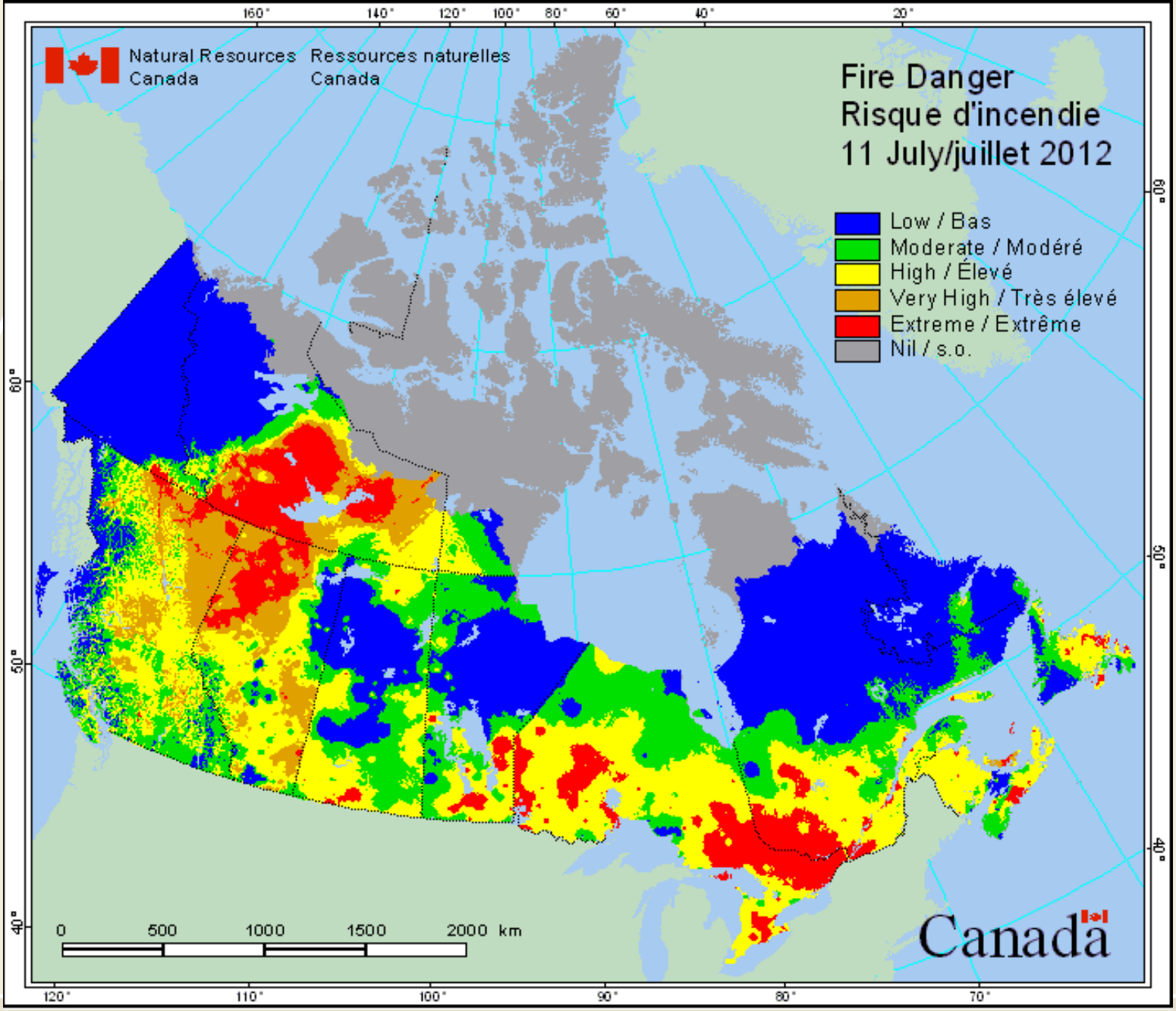




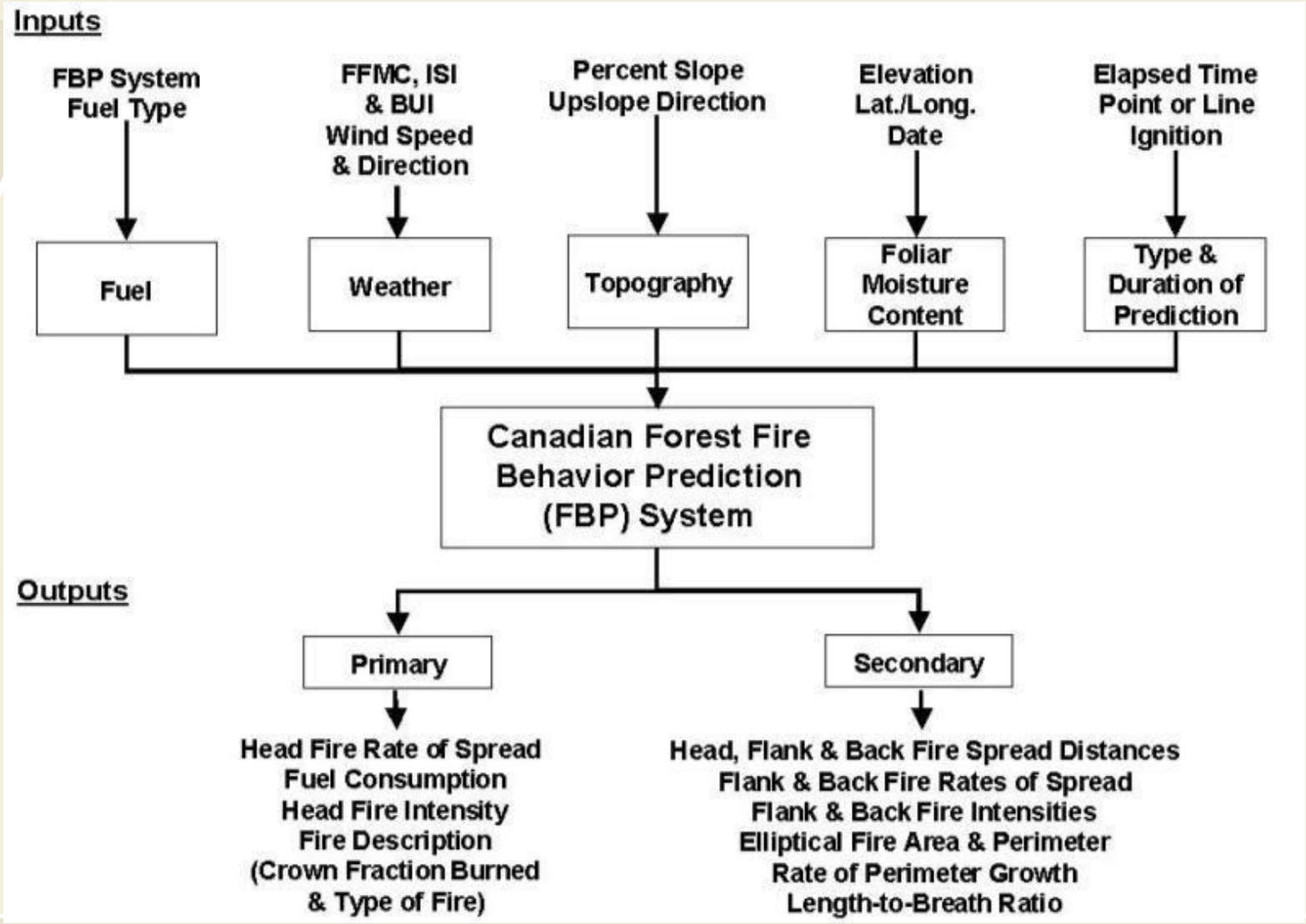
The Canadian Fire Danger Rating System

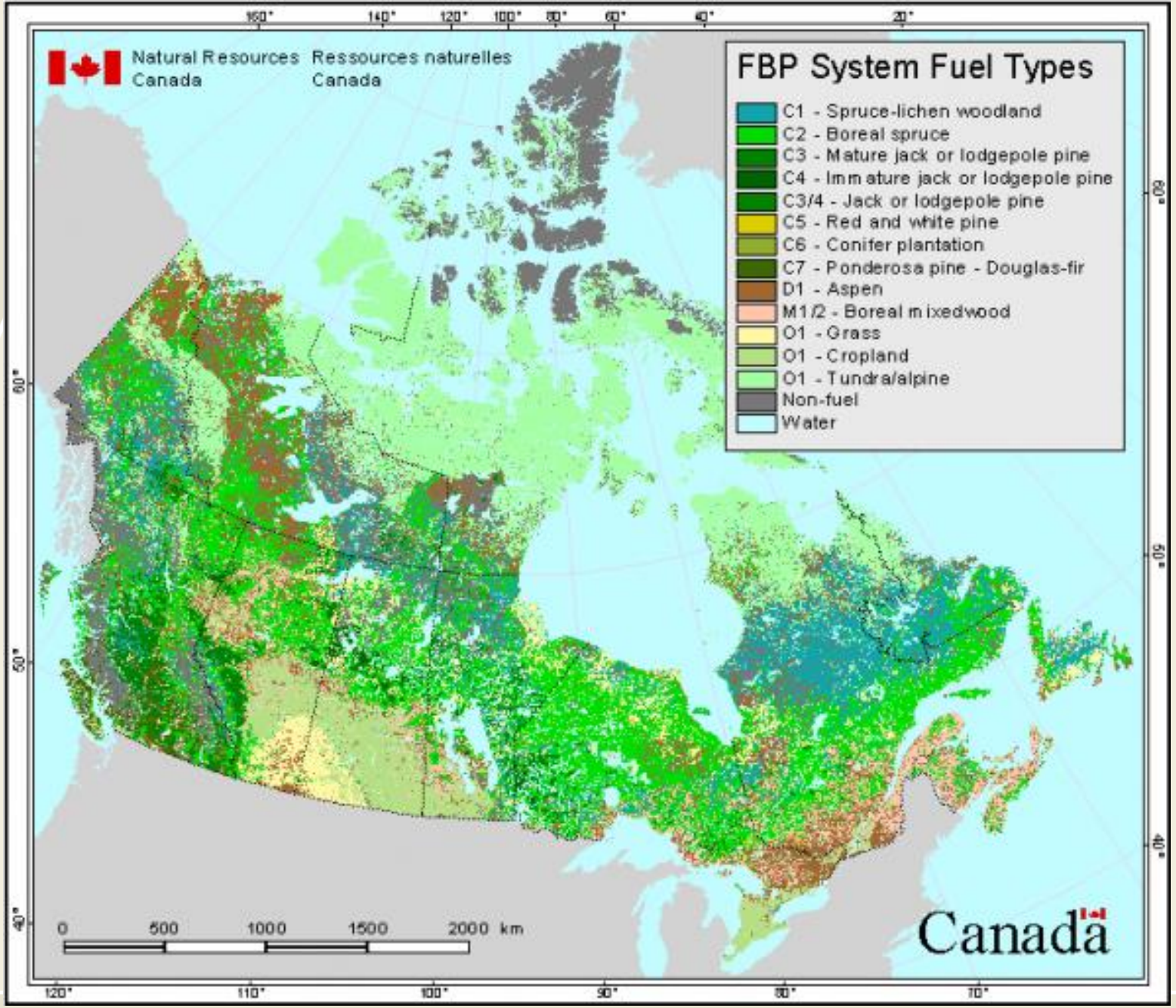


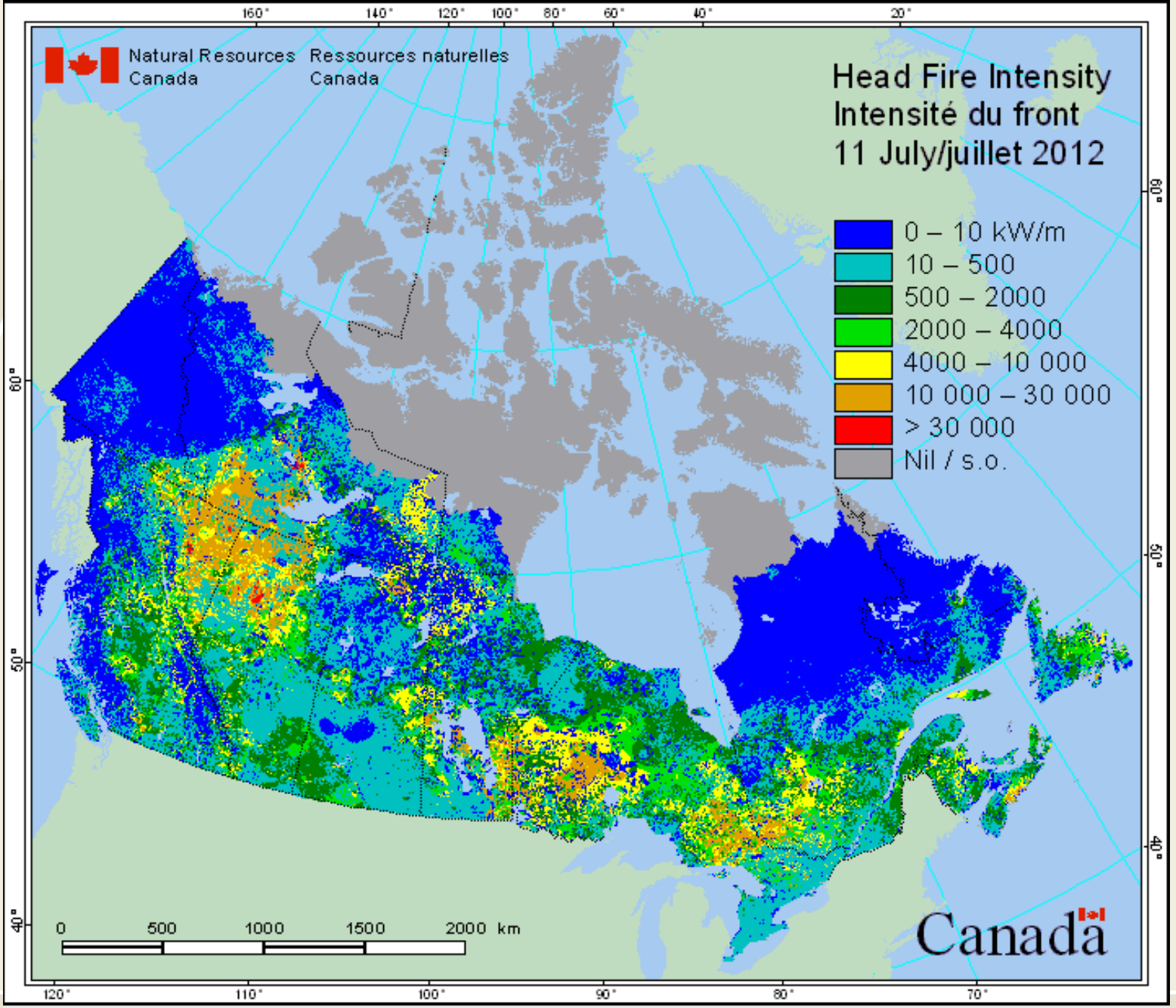

Fire Weather Observations
Temperature
Relative Humidity
Wind
Rain
Wind
Temperature
Relative Humidity
Rain
Temperature
Rain
Fuel Moisture Codes
Fine Fuel Moisture Code (FFMC)
Duff Moisture Code (DMC)
Drought Code (DC)
Initial Spread Index (ISI)
Buildup Index (BUI)
Fire Behavior Indexes
Fire Weather Index (FWI)


Natural Resources Canada
Ressources naturelles Canada
Fire Danger
Risque d'incendie
11 July/juillet 2012
Low / Bas
Moderate / Modéré
High / Élevé
Very High / Très élevé
Extreme / Extrême
Nil / s.o.
0 500 1000 1500 2000 km
Canada

Structure of the Canadian Forest Fire Behavior Prediction (FBP) System




Natural Resources Canada
Ressources naturelles Canada
FBP System Fuel Types
C1 - Spruce-lichen woodland
C2 - Boreal spruce
C3 - Mature jack or lodgepole pine
C4 - Immature jack or lodgepole pine
C3/4 - Jack or lodgepole pine
C5 - Red and white pine
C6 - Conifer plantation
C7 - Ponderosa pine - Douglas-fir
D1 - Aspen
M1/2 - Boreal mixedwood
O1 - Grass
O1 - Cropland
O1 - Tundra/alpine
Non-fuel
Water
0 500 1000 1500 2000 km
Canada


Natural Resources Canada
Ressources naturelles Canada
Head Fire Intensity
Intensité du front
11 July/juillet 2012
0 – 10 kW/m
10 – 500
500 – 2000
2000 – 4000
4000 – 10 000
10 000 – 30 000
> 30 000
Nil / s.o.
0 500 1000 1500 2000 km
Canada

CFFDRS – Its usage

- Wildfire Management
  - Used tactically and strategically by fire agencies to help the basic fire environment most activities
    - e.g., Imposing restricted fire zones (fire bans- public and industrial), fire ignition risk, fire growth potential, fire intensity, potential suppression resource effectiveness, resource preparedness and positioning, prioritization of suppression targets, fireline safety, evacuation planning, values protection
    - e.g., PB planning, fuels management planning, training
- Science
  - e.g., climate change impacts and adaptation scenario development, carbon monitoring and accounting, smoke transport modelling…

CFFDRS – Its usage

- Used universally throughout Canada
  - As well as in a number of other countries

- We think a major part of its success in uptake is due to the philosophical approach: scale and simplicity
  - Observing key processes in the field
  - Development of modular empirically-based models of process
    - Using very simple physics/physical reasoning to frame model structure
  - Creation of simple interpretative tools/applications

CFFDRS – Its Issues

- Simple Issues (but important for a empirically- based system)
  - Higher resolution of data available
    - Temporal and spatial resolution of weather
    - Spatially-detailed, fine resolution forest composition data (satellite, land-based, …lidar)
  - New sources of information
    - Satellite observations (e.g., greenness, forest floor moisture)
    - Direct, real-time measurement of fuel moisture
  - Ease in accessing, synthesizing and displaying/using large amounts of information
- ALSO of course ongoing advances in fire science

CFFDRS – Its Issues

- More Complex issues
  - Some fuel types and modifications of fuel types not addressed
  - Current system is a child of the fire exclusion paradigm
  - The challenges in the wildland fire management decision-making environment have changed
    - Wildland-urban interface and community risk reduction, changing fuels and forest health, climate change, public expectation
  - A new generation CFFDRS will not solve these problems
    - Provide information to help support decisions

CFFDRS-Next Generation

- This is a continuing evolution of the system not a tear down/rebuild (in keeping with the ongoing philosophy)
  - The goals:
    - Provide systems that use the data available to enable fire management to engage in risk assessment and determine appropriate response to unwanted fire
    - Keep the approach that has lead to success of the system while introducing more flexibility into the models

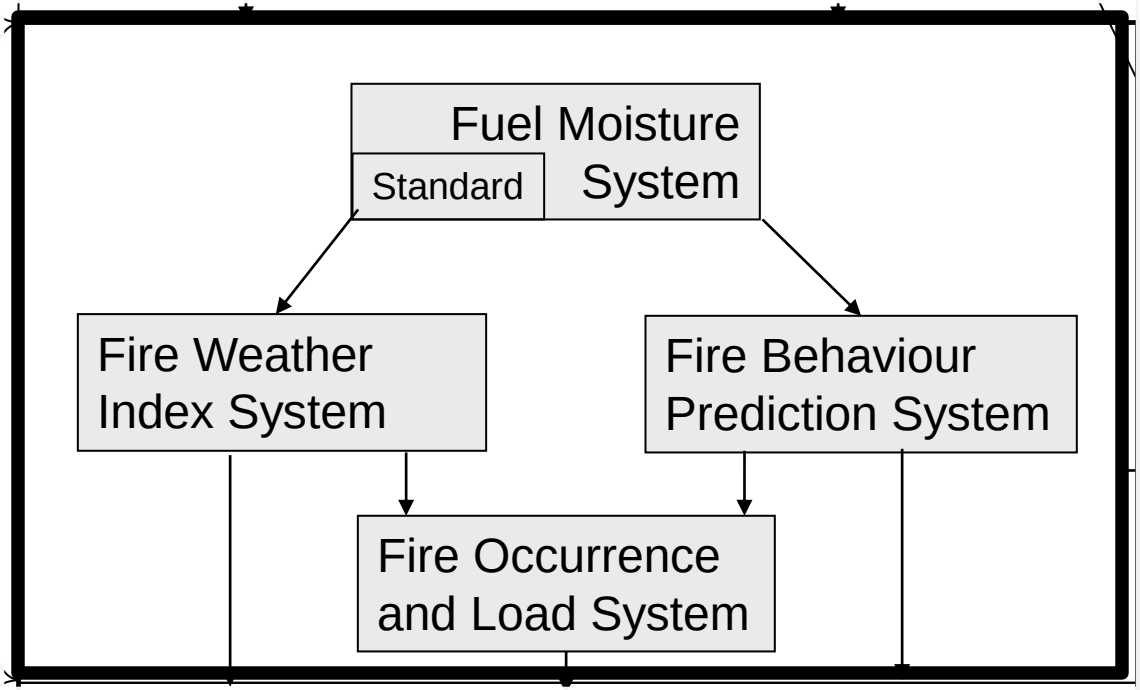
Current thinking

- Our broader research program will focus mainly on three areas and is linked with our program of delivery of these products:
  - New inputs and drivers to danger rating
    - Core information/data needs of a new generation of the CFFDRS
    - Working with our FMIS group to determine how best to deliver
  - Core components of the CFFDRS
    - e.g., Behaviour, fuel moisture, fire occurrence
  - Integrated science and management applications
    - e.g., Emissions modelling, smoke modelling

……This is a work in progress

CFFDRS-NG – Approach

- Reanalysis of existing CFS data with newer model forms
  - e.g. Fuel load specific consumption, generalized conifer crown fire spread model
- Gathering new data from field (where possible) and other published/available sources
  - e.g. fire behaviour, fuel consumption fuel moisture, fuel structure, wildfire obs., weather models
- Using more explicit characterization of basic key processes
  - Not a major leap to detailed physical modelling but a step toward making some key implicit relationships in the system more explicit
    - e.g., dual equilibrium spread model, direct linkages between spread rate and wind/moisture, direct use of forest structure information
  - This will be hidden from all but the most advanced users


Fuel Moisture System
Standard
Fire Weather Index System
Fire Behaviour Prediction System
Fire Occurrence and Load System

Core System : FBP

Future components of the Fire Behaviour Prediction System

- Probability of ignition sustainability
- New point fire acceleration model
- Mixed surface/crown initiation/crown fire spread model
  - New explicit surface fire models driven directly by direct estimates of wind and moisture (specific to a stand)

CORE System : FBP cont'd

- *Fuel load specific consumption models*
  - *Forest floor, D&D, aerial fuels*
  - *Carbon*
- Combustion zone characteristics models/outputs
  - Residence time, flame front depth, flame length, smouldering/flaming partitioning, flame temperature, emissions
- Eventually…..Fuel break breaching and spotting probability models

Fire behaviour today in CFFDRS

FBP System models are based on

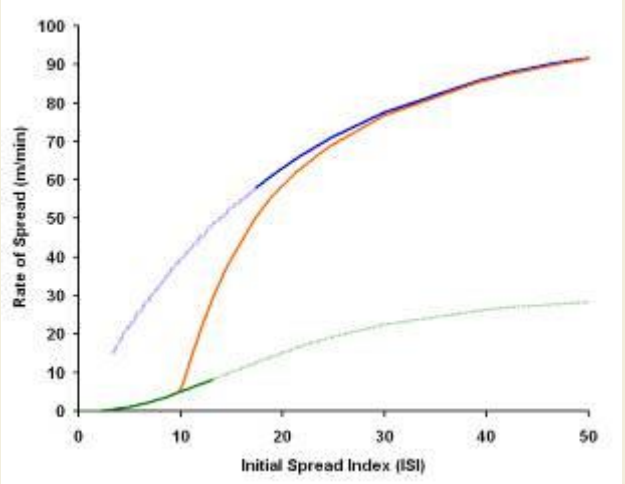
- Observations of replicated sets of experimental burns in a range of important fuel types
  - Also wildfire and Rx Fire observations

- There are 16 such fuel types in 3 broad groupings
  - Conifers
  - Deciduous mixedwoods
  - Open

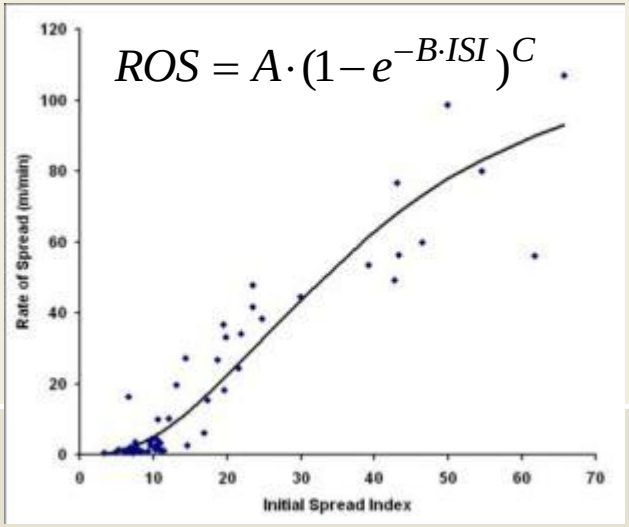
CFFDRS- Spread Rate

- Models for a specific fuel type must encapsulate potential for surface and also crown fire
  - Van Wagner proposed a dual model form to capture this

- Models link wind and moisture through the FWI System's Initial Spread Index
  - Unitless blend of wind and moisture for a standard conifer type



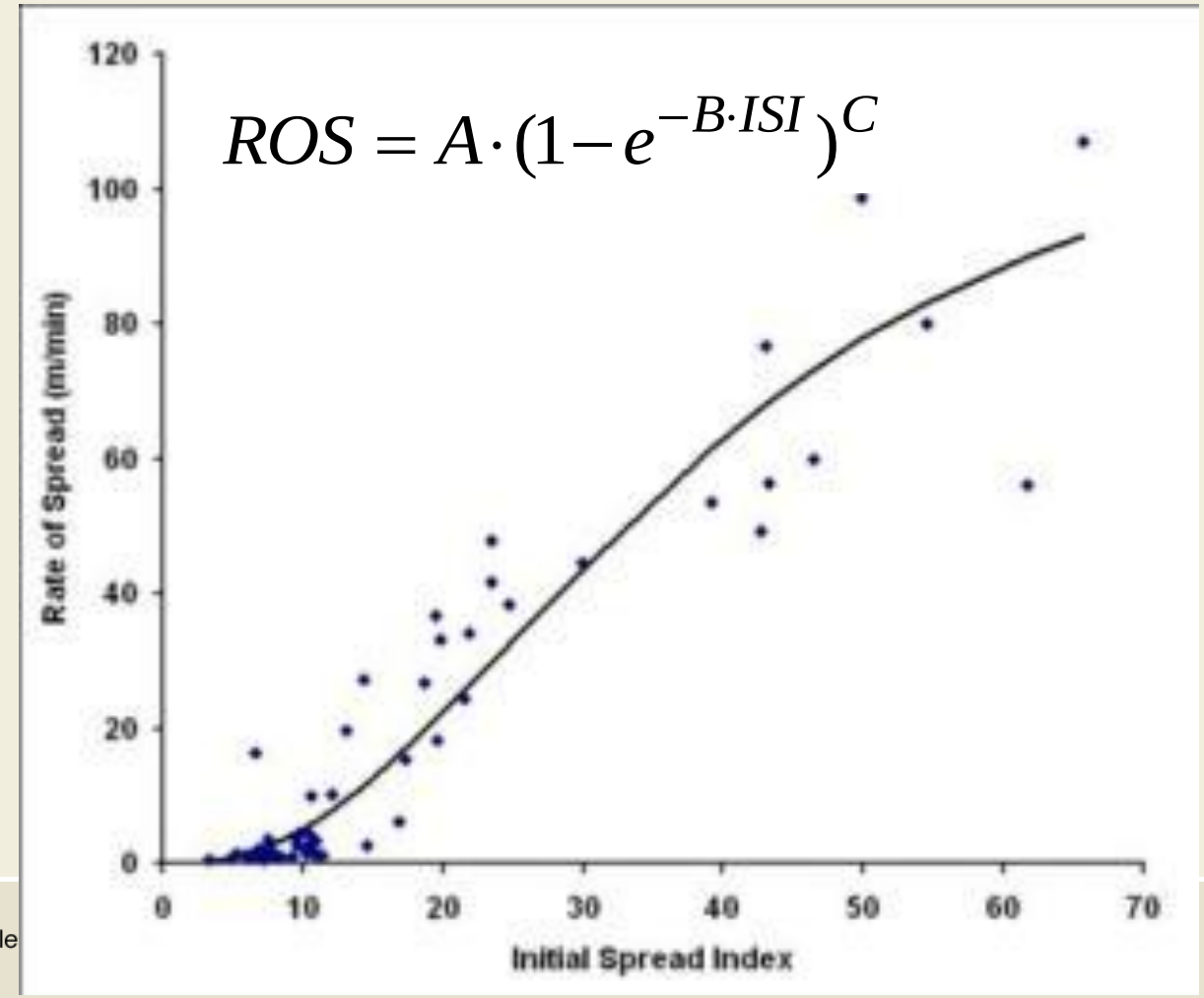
e.g., Dual equilibrium ROS



CFFDRS- Spread Rate

A lot of important detail get implicitly rolled into this simple single equation approach

- point when surface fire begins crowning
- instand wind reduction
- Maximum spread rates
- Interaction of wind and moisture



CFFDRS- Spread Rate

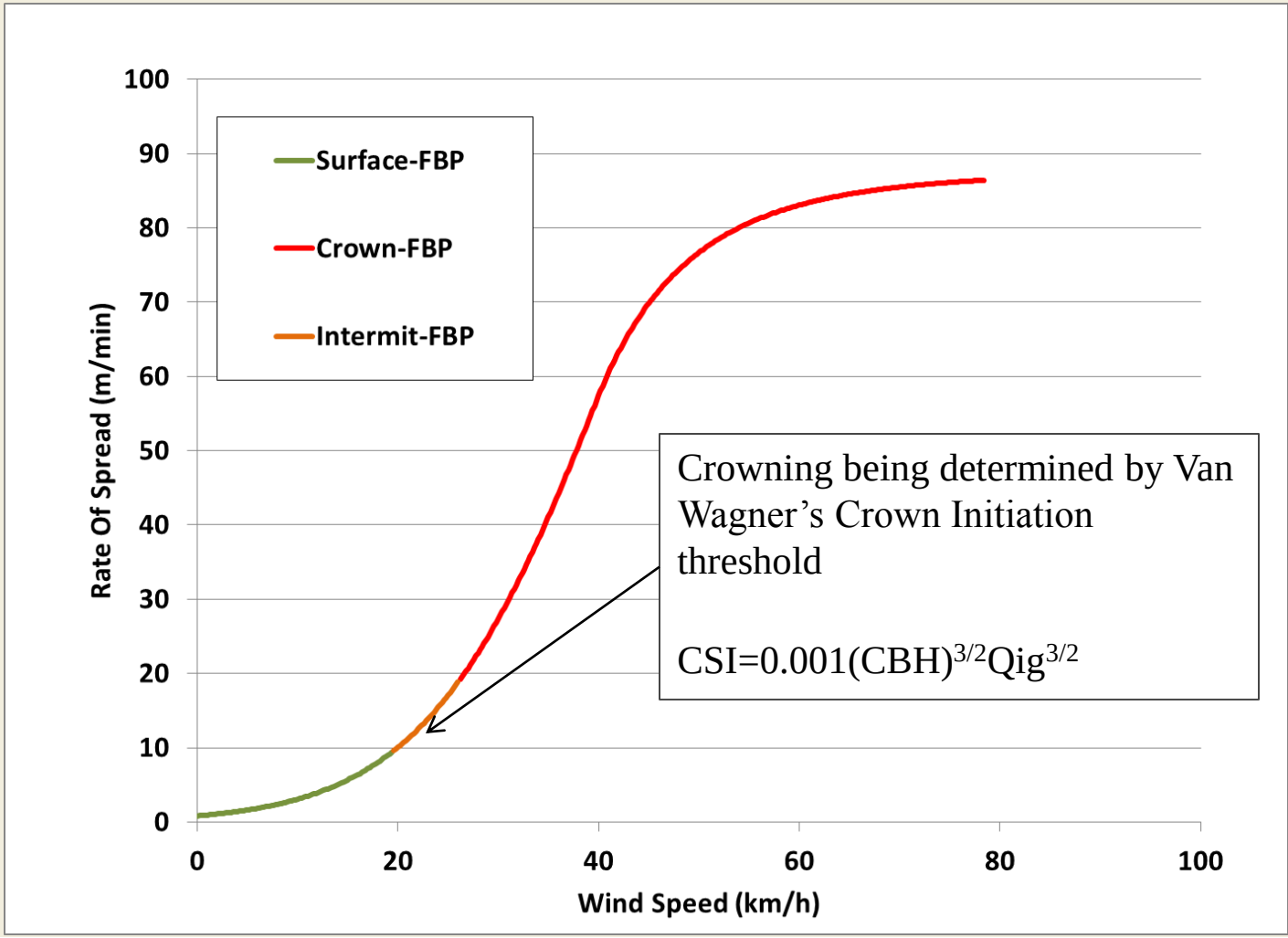
C-3 - Jack Pine

FFMC=10% (91)

BUI=60

FMC=120%

CBH =8 m



CFFDRS- Spread Rate

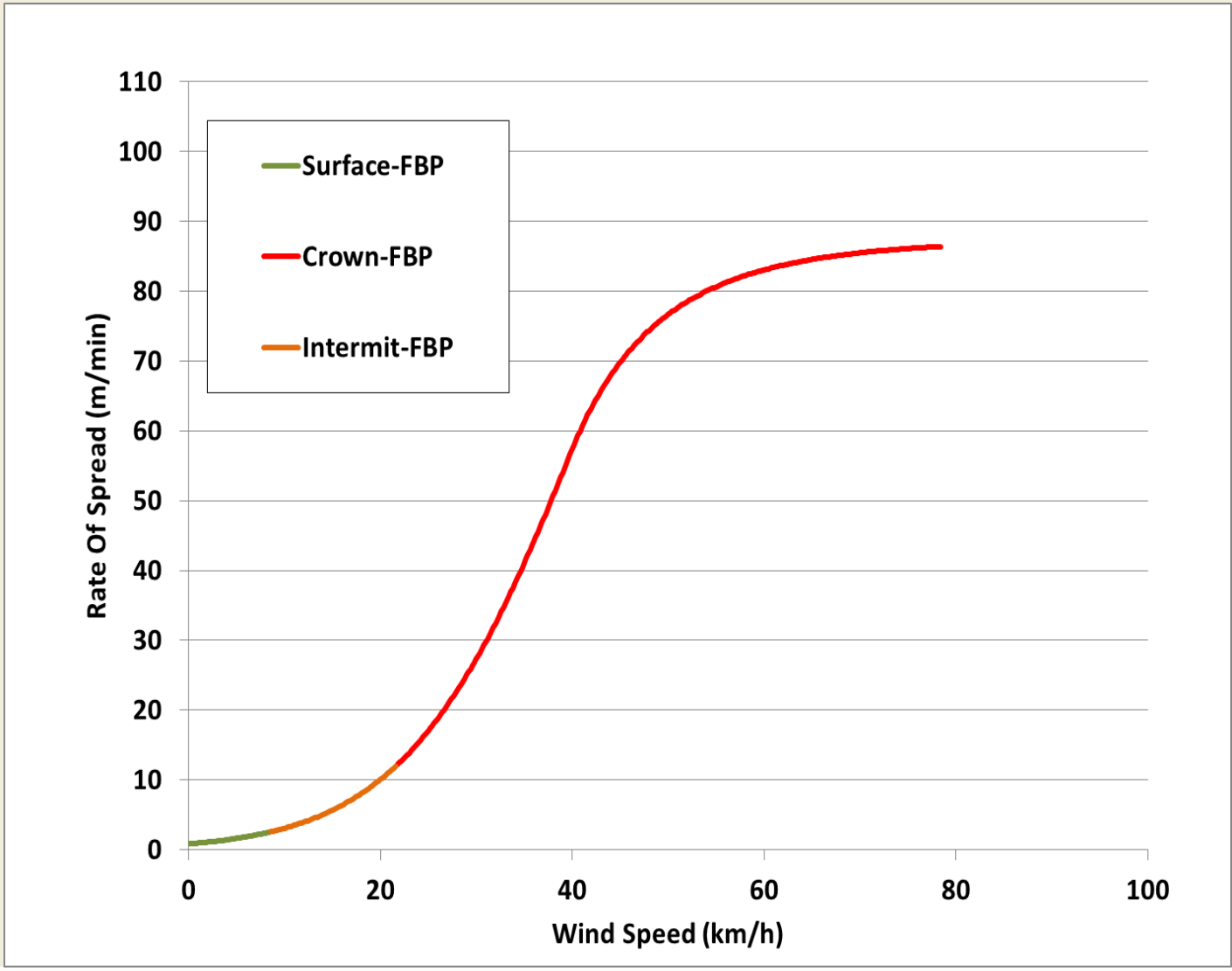
C-3 –Jack Pine

FFMC=10% (91)

BUI=60

FMC=120%

CBH=4 m



CFFDRS- Spread Rate

C-3

FFMC=91

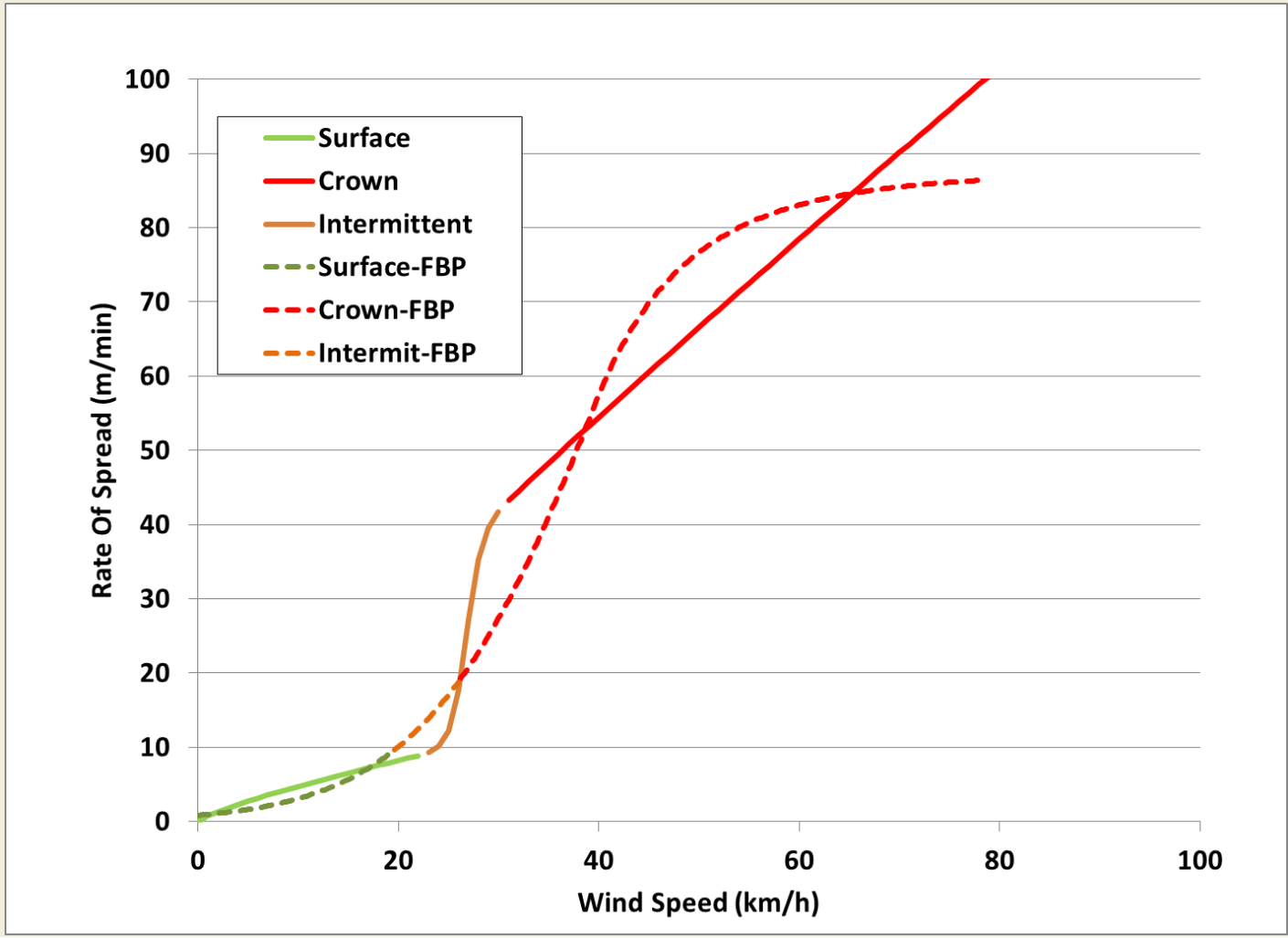
BUI=60

FMC=120%

MC_{litter}=10%

$Wind_{IN}$=25%

CBD=0.15kg/m^3



CFFDRS-NG : Spread Rate

Future Spread Rate models

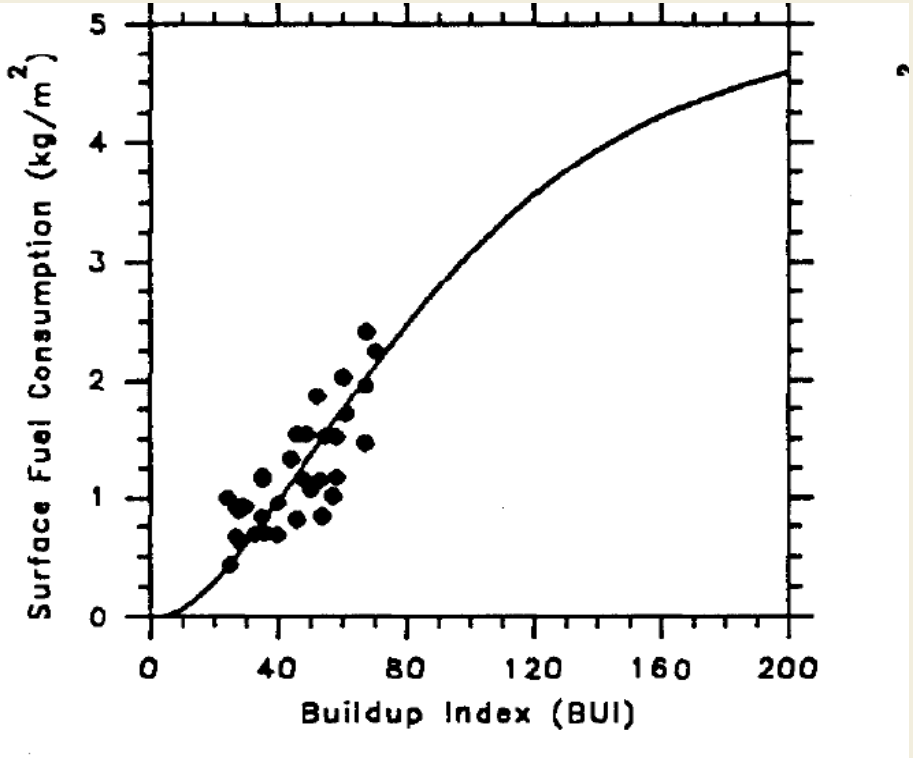
- To accomplish this general ‘dual’ or multi-phase model for rate of spread
  - Reanalysing our surface fire data sets to create a set of forest floor cover specific models that depend on :
    - Instand wind
      - estimated based on stand characteristics
    - Fuel moisture content
      - New forest floor cover specific models that account for stand closure (solar radiation)

CFFDRS - Fuel Consumption

Similar to Spread Rate

- A model for each fuel type based on experimental observations
- One of the main limitations:
  - Fuel load is implicitly assumed

    (except in the grass model)



$$SFC = A \cdot (1 - e^{-B \cdot BUI})^{C}$$

CFFDRS : Fuels

- IN FBP today
  - essentially 16 fuel types each described mostly qualitatively
    - e.g., species, structure

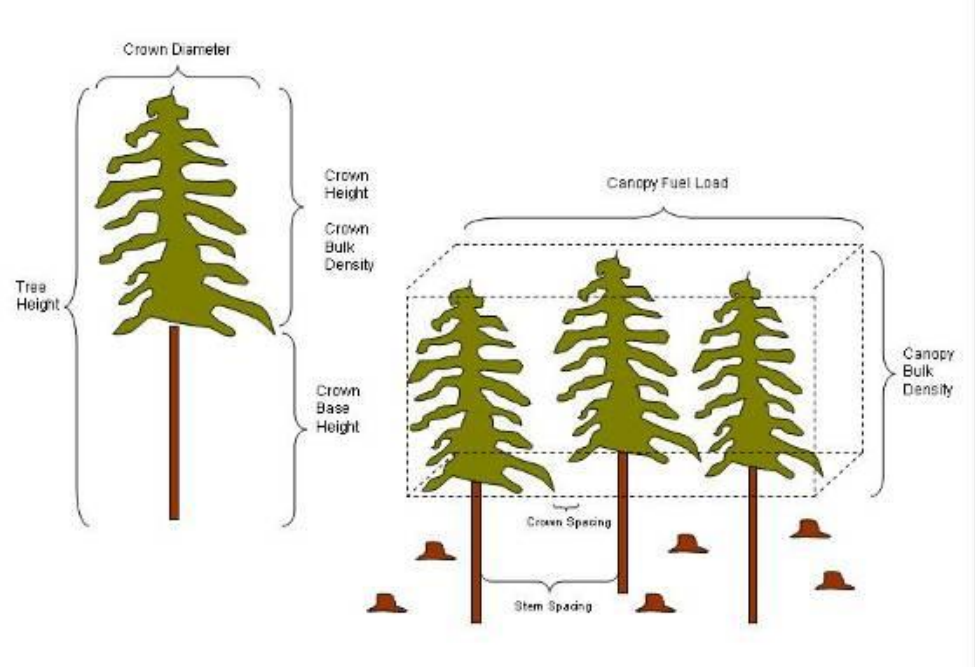
Forest Floor Continuous feathermoss; moderately deep compact organic layer
Surface and ladder fuels Spares conifer understory may be present; sparse down woody fuels; tree crowns separated from the ground
Stand Structure and composition Fully stocked, mature jack or lodgepole pine stands

CFFDRS-NG : Fuels

- Maintaining the current benchmark fuel types initially (16)
  - Simply completely defining in terms of loads, depths, lengths, densities etc.
  - This will be invisible to those who don't care
- Working with field personnel to add some new sub-types into groups to address established holes
- This approach will allow users to quantitatively describe a specific fuel complex when the need is there.
  - The lack of this ability has been the number one complaint about the system

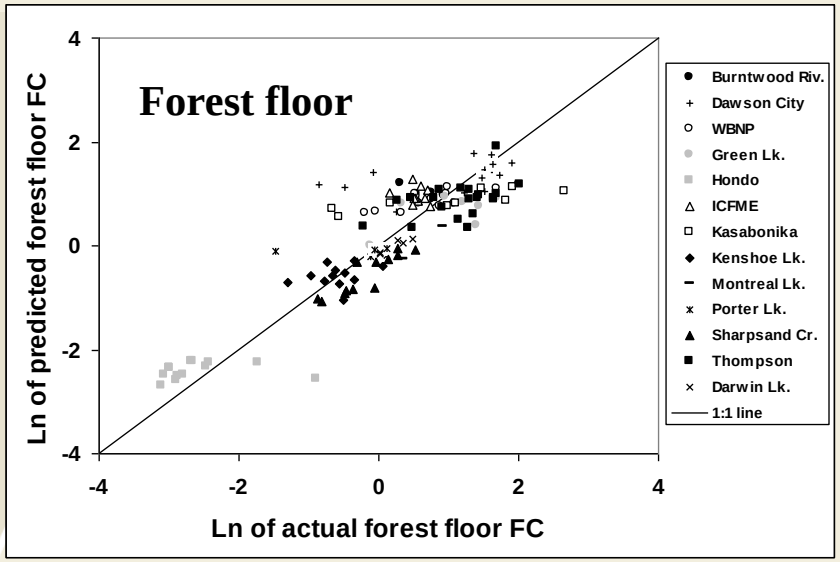
CFFDRS-NG : Fuels

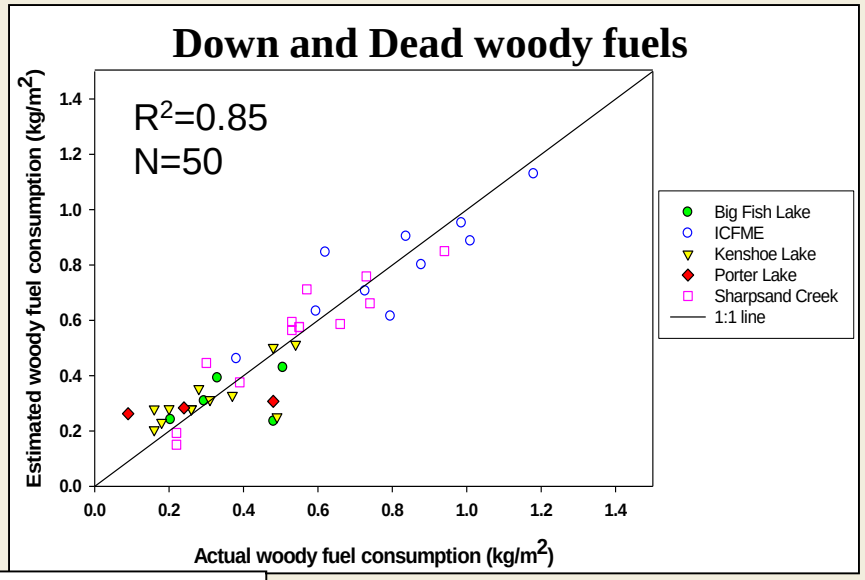
- Fuel types will be become more explicitly defined and quantitative ->>fuel models
- e.g.,
  - Fuel loads
  - Stand density
  - Forest floor cover/litter load
  - Organic layer depth

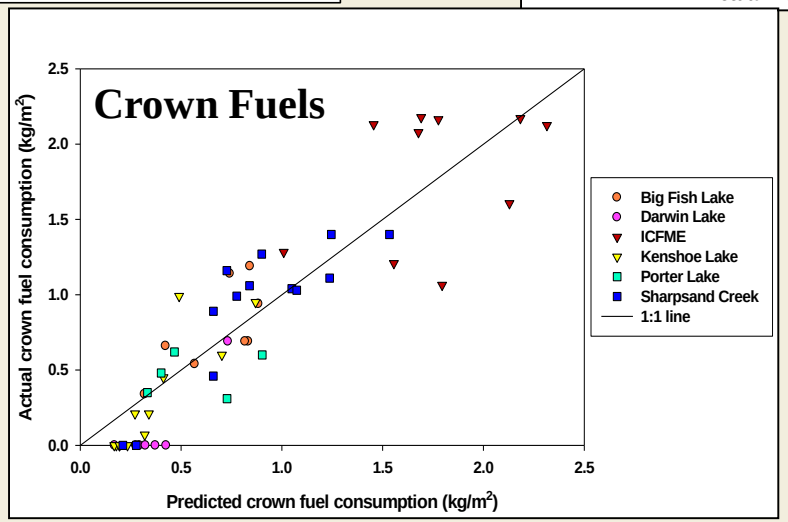


- Fuel models will allow adjustable fuel loads

Fuel consumption – Load dependent







CORE System : FBP Challenges

- *Sources of empirical data (a foundation of the system)*
  - *Experimental burning*
    - *We'd be glad to partner with agencies still….*
    - *….these are really big undertakings however*
      - *cannot run programs like during the 70's and 80's*
    - *….There are some key gaps ….*
  - *FBAN observations*
    - *This is a resource we need to tap consistently for targetted observations.*
      - *E.g., fire transitions, shoulder periods of day, foliar moisture effects?, mixedwood*
  - *Remote sensing*

CORE System : FBP Challenges

Digression:

Experimental burning: Some data gaps/model weaknesses (a short non-exclusive list)

- *Initiating (point) fire growth to equilibrium*
- *Surface fire and transition to crowning*
  - *Our surface fire datasets are limited*
- *Early morning/late evening spread*
  - *Come from FGM pushing spread overnight*
- *Insect kill effects (e.g., MPB)*
- *Effect of green vegetation on spread rate*
- *Fire brand generation (numbers)*
- *……*

CORE System : FBP Challenges

- *Sources of empirical data (a foundation of the system)*
  - *Experimental burning*
    - *We'd be glad to partner with agencies still….*
    - *….these are really big undertakings however*
      - *cannot run programs like during the 70's and 80's*
    - *There are some key gaps ….*
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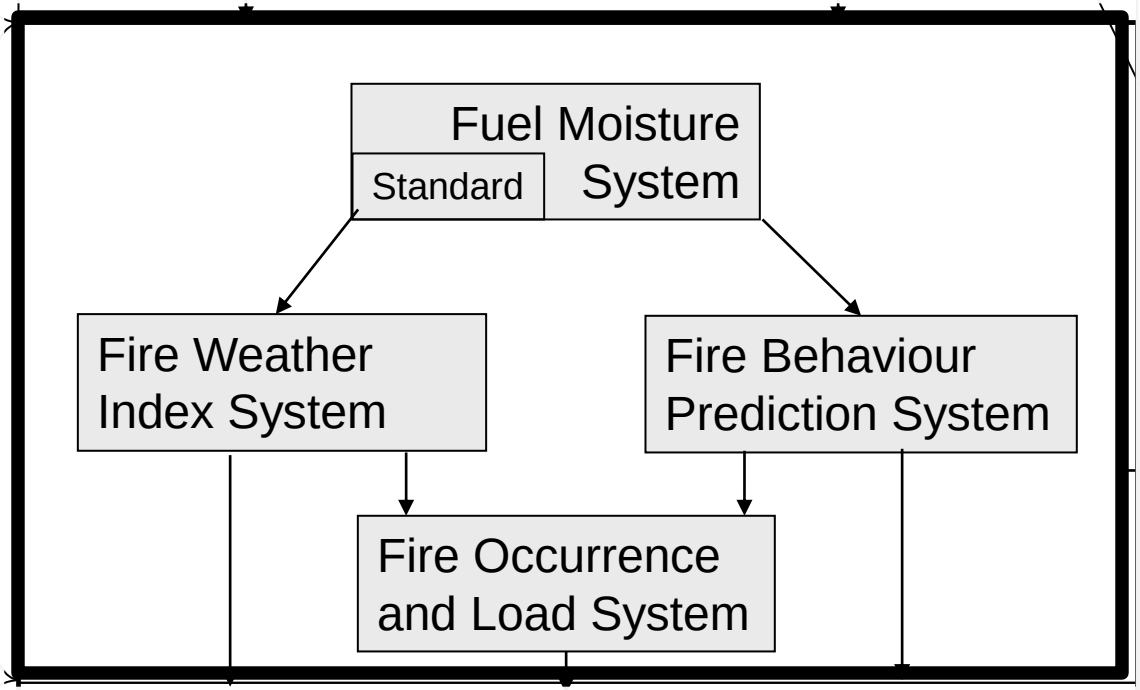

Fuel Moisture System
Standard
Fire Weather Index System
Fire Behaviour Prediction System
Fire Occurrence and Load System

CORE System : FWI System

Where are we today?

- Moisture codes and index calculation methods relatively unchanged since 1970
  - Single fuel type, relative indicators of fire behaviour.
- Weather measurement timing originates from 1938 methodology.
- …..but the FWI System still does a remarkably good job of capturing regional fire activity.

CORE System : FWI System

…..The flow of the basic system will remain largely intact and as is, with some simple clarifications/updates

- As before the Standard moisture models in FWI System will be tracking a mature closed canopy jack pine stand.

- FFMC : Some modification but same data requirement for the standard FWI system stand
  - Inconsistencies between daily, hourly calculation and diurnal adjustment are reconciled…by making the diurnal weather driving the standard daily calculation explicit
  - Users then could then adjust for local differences or season
- Option for adjusting for underlying moisture in organic layer
  - A version of this currently exists

CORE System : FWI System

…..The flow of the basic system will remain largely intact and as is, with some simple clarifications/updates

- DMC/DC
  - Similarly DMC and DC standards kept (same general data requirements)
    - Drying rate (evapotranspiration) model updated
      - solar radiation
      - wind

CORE System: Moisture specifics

- Litter/fine fuel moisture
  - More calibrations between FFMC and litter moisture documented
    - A number of these exist already
  - New methods for tracking litter moisture in several important forest floor cover types
    - solar radiation included via LAI of overstory
    - instand wind estimated for key forest types based on density
  - Model for tracking moisture in elevated fine fuels (no organic layer influence)
    - The new grass model is a specific case of this
- The standard FFMC/moisture content conversion

CORE System: Moisture specifics

- Organic layer
  - Upper organic (DMC) – still a key layer for us
    - Modifying drying rate (ET) model
      - Solar radiation, wind, overstory type (and density)
      - General forest floor characteristics
  - Deeper organic (DC)
    - Update of ET models
    - Include a general effect of underlying soil strata
  - Peat
    - We are also trying to develop some moisture indicators that will provide information about vulnerability of peatlands

CORE System: Moisture specifics

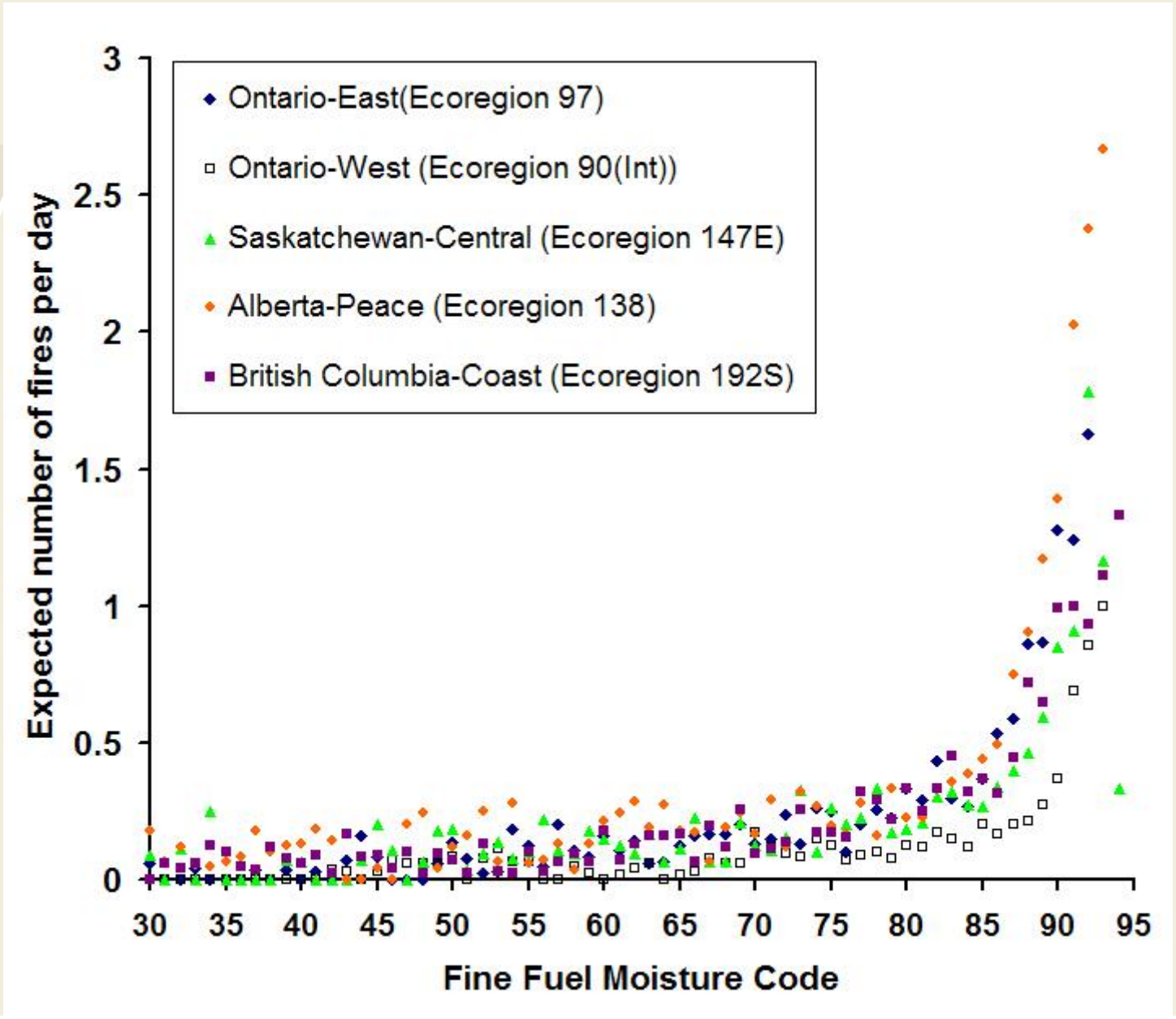
- Foliar Moisture and green up timing
  - new weather-based and tree physiology-based foliar moisture content model and leaf flush model
    - Replacing the geographically based one
  - New weather-based grass curing function
  - Also we will be exploring the utility of satellite green up observations for these variabiles (INPUTS)

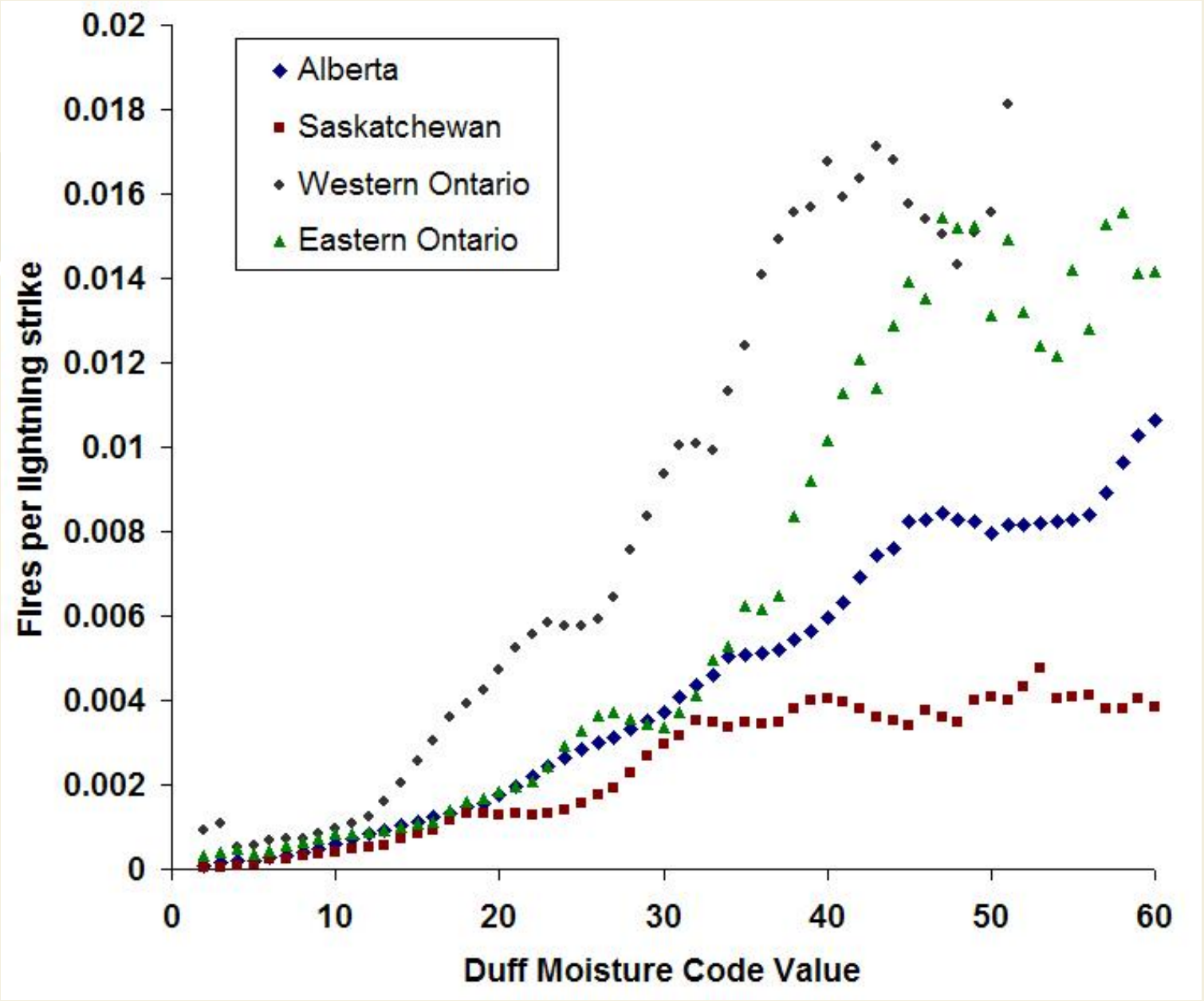
CORE System : Fire occurrence

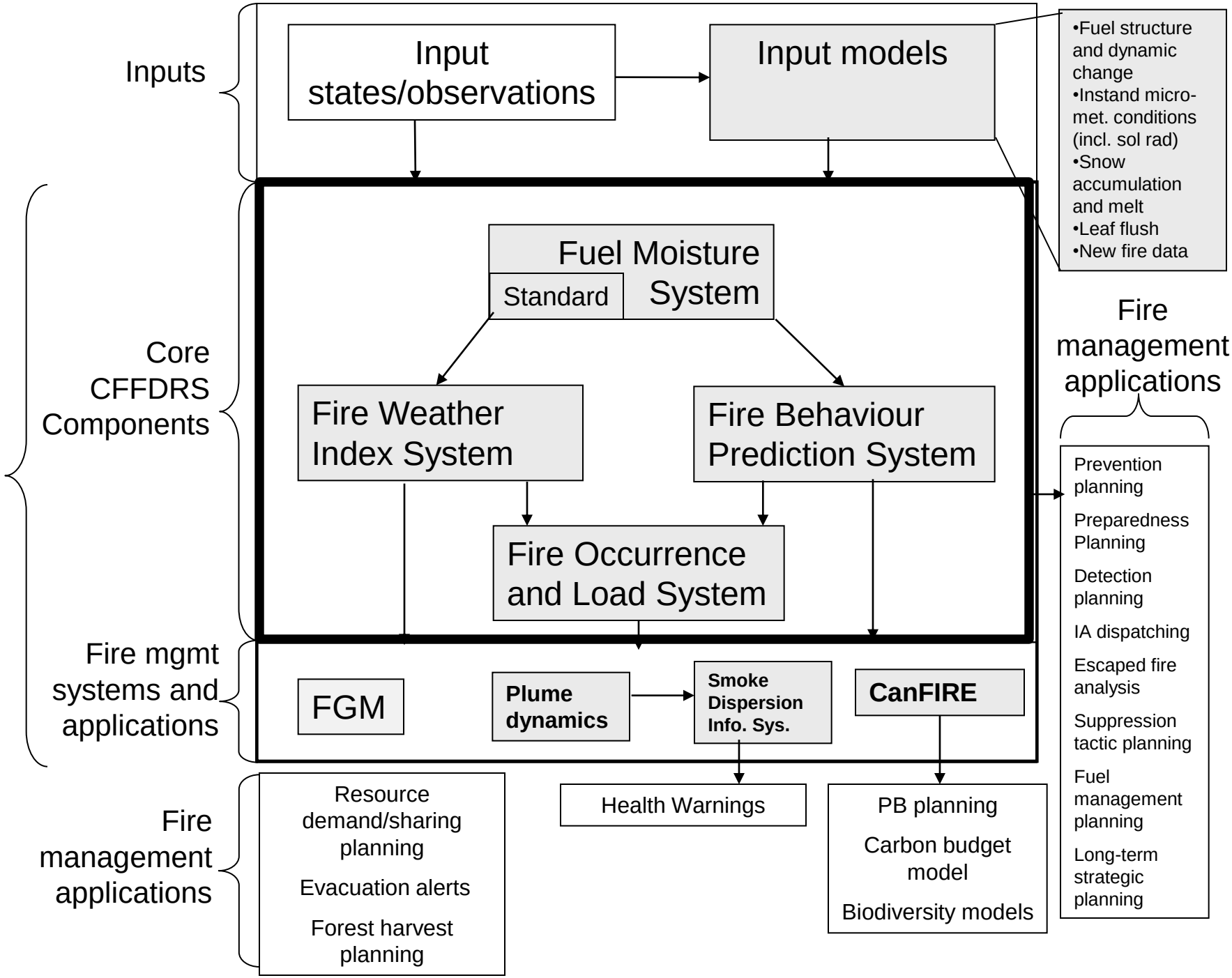
- Models to carry out mapping of fire occurrence potential (human and lightning) to be developed for management jurisdictions across Canada.
  - Provided daily on CWFIS

    and
  - Provided to agencies to adopt into Info systems if desired

- Also planning on developing methods of assessing the potential occurrence of ‘problem’ fires and overall expected daily fire load


Ontario-East(Ecoregion 97)
Ontario-West (Ecoregion 90(Int))
Saskatchewan-Central (Ecoregion 147E)
Alberta-Peace (Ecoregion 138)
British Columbia-Coast (Ecoregion 192S)
Expected number of fires per day
0
0.5
1
1.5
2
2.5
3
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Fine Fuel Moisture Code

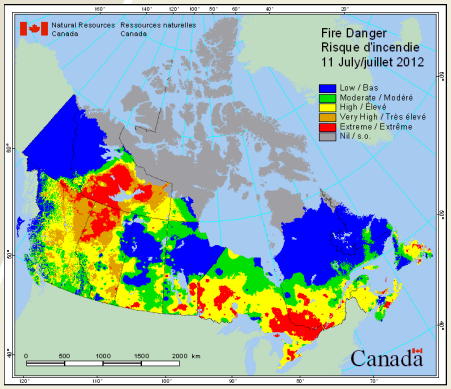

Alberta
Saskatchewan
Western Ontario
Eastern Ontario
Fires per lightning strike
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
10
20
30
40
50
60
Duff Moisture Code Value

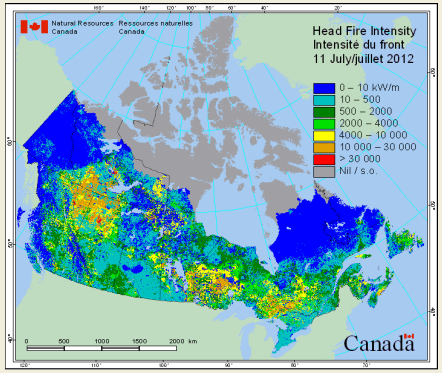

Inputs
Input states/observations
Input models
•Fuel structure and dynamic change
•Instand micro-met. conditions (incl. sol rad)
•Snow accumulation and melt
•Leaf flush
•New fire data
Core CFFDRS Components
Fuel Moisture System
Standard
Fire Weather Index System
Fire Behaviour Prediction System
Fire Occurrence and Load System
Fire management applications
Prevention planning
Preparedness Planning
Detection planning
IA dispatching
Escaped fire analysis
Suppression tactic planning
Fuel management planning
Long-term strategic planning
Fire mgmt systems and applications
FGM
Plume dynamics
Smoke Dispersion Info. Sys.
CanFIRE
Health Warnings
PB planning
Carbon budget model
Biodiversity models
Fire management applications
Resource demand/sharing planning
Evacuation alerts
Forest harvest planning

More Challenges

- The list is long…But one critical one is Tech Transfer
  - We are working with our CFS FMIS group to get new hourly/daily information products out for use/evaluation on their web portal.
    - Over the next year we hope to role out versions of national lightning and human caused fire.
    - New moisture/models indexes (along with solar radiation estimation methods)
  - We will work with individual agencies to test newer models and develop tech transfer training.
    - And ideally collect validation and modelling data

Fire Behaviour in the Next Generation Canadian Forest Fire Danger Rating System





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